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ORIGINAL PAPER

The Sensory Profiles, Eating Behaviors, and Quality of Life of Children with Autism Spectrum Disorder and Avoidant/Restrictive Food Intake Disorder

Reyhan Calisan Kinter[1] · Burcu Ozbaran[1] · Ipek Inal Kaleli[1] · Sezen Kose[1] · Tezan Bildik[1] · Mohammad Ghaziuddin[2]

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Abstract
Eating disorders frequently accompany autism spectrum disorder (ASD). One such novel eating disorder is avoidant/restrictive food intake disorder (ARFID). This study compares the eating attitudes, quality of life, and sensory processing of typically developing children (TDC), autistic children, and autistic children with ARFID. A total of 111 children aged 4–10 with a diagnosis of ASD and ARFID (n = 37), ASD without ARFID (n = 37), and typical development (n = 37) were recruited. After an interview in which Childhood Autism Rating Scale (CARS) was administered, Child Eating Behavior Questionnaire (CEBQ), Pediatric Quality of Life Inventory (PedsQL), Social Responsiveness Scale (SRS) and Sensory Profile (SP) were completed by caregivers. Autistic children with ARFID had higher scores in CEBQ subscales relating to low appetite and lower scores on the subscales associated with weight gain. Both groups of autistic children scored lower than TDC on all PedsQL subscales and autistic children with ARFID had lower social QL scores than both groups. SRS scores were highest in autistic children with ARFID, followed by autistic and typically developing children. CARS scores were similar in both groups of autistic children, but higher than TDC. Auditory, vision, touch, multi-sensory, oral processing scores; as well as all quadrant scores, were significantly lower in autistic children with ARFID. Oral sensory processing scores were found to be the most significant predictor of ARFID comorbidity in ASD and reliably predicted ARFID in autistic children in the clinical setting. Autistic children with ARFID demonstrate differences in social functioning, sensory processing, eating attitudes, and quality of life compared to autistic and TD children.

Keywords Avoidant/restrictive food intake disorder · Autism spectrum disorder · Sensory profile · Eating behavior · Quality of life

✉ Ipek Inal Kaleli
ipekinal93@gmail.com

[1] Department of Child and Adolescent Psychiatry, Faculty of Medicine Children's Hospital, Ege University, Kazimdirik Mh. Ankara Cd, Izmir 35030, Turkey

[2] Department of Psychiatry, University of Michigan, Ann Arbor, MI, USA

Autism spectrum disorder (ASD) is characterized by persistent difficulties in social interaction and communication, understanding, developing and maintaining relationships, atypical sensory processing, repetitive behaviors, and circumscribed interests [1]. Autism generally becomes evident in early childhood and may impair daily functioning. In addition, autism is frequently complicated by other psychiatric comorbidities such as attention deficit hyperactivity disorder; mood, anxiety, sleep, and eating disorders [2].

Avoidant/Restricted Food Intake Disorder (ARFID) is a novel eating disorder recently introduced in the DSM-5. ARFID is characterized by an aversion to eating or picky eating habits. This reluctance to food intake may be attributed to several factors, including sensory qualities of the food item (such as its smell, appearance, etc.); apparent lack of interest in eating or food; or concern about aversive consequences of eating (such as fear of choking or vomiting after ingestion). A diagnosis of ARFID is made when aversion to feeding results in either a significant nutritional deficiency, substantial weight loss or retardation of growth in children, reliance on alternative feeding methods or supplements, deterioration of psychosocial functioning, or a combination of the aforementioned criteria. As such, the study of ARFID is important as it has physical and nutritional implications. Although substantial weight loss and growth retardation is a criterion for diagnosis and a frequently reported consequence of ARFID in literature [3] there are reports of normal and overweight children resulting from a restricted selection of high-calorie foods [4]. In addition to its varied clinical and physical presentation, the eating problems arising from ARFID should not be better explained by another medical or psychiatric disorder, cultural differences, lack of food resources, or, as opposed to anorexia nervosa, a disturbance of body image or shape [1].

The co-occurrence of eating/feeding disorders and neurodevelopmental disorders, including autism have been frequently reported. Eating problems have been reported in as much as 80% of children with neurodevelopmental disorders compared to 25% of children in the general population [5]. Of the eating disorders often seen with autism spectrum disorder, anorexia nervosa (AN) is frequently studied and reported [6]. This association of autism and anorexia may be due to a shared vulnerability that interacts with environmental factors to cause both disordered eating and autistic traits. Much like AN, disordered eating patterns may arise due to sensory sensitivities, emotional difficulties, autistic thinking patterns, a need for control and predictability, or a combination of these factors for ARFID [6, 7]. However, studies looking into autism and ARFID comorbidity remain few compared to other eating disorders. A recent genetic study on autism estimated that the prevalence of Avoidant/Restrictive Food Intake Disorder (ARFID) could be as high as 21% [8] and although a direct diagnosis of ARFID was not made, in a review of 63 case reports and series, severe vitamin deficiencies in individuals on the autism spectrum was reported [9]. In another recent study involving 46 autistic children from Sweden, 76% were found to have feeeding problems while 28% met the criteria for ARFID [10]. Although autistic children may demonstrate symptoms that directly overlap with those of ARFID, such as picky eating and food aversion due to sensory qualities of food, few studies explore the cooccurrence and the relationship between these two conditions [11]. Atypical sensory processing appears to be a potential moderator for both disorders, which makes this topic particularly intriguing.

Both autism and ARFID are characterized by atypical sensory processing. Sensory processing encompasses the acquisition and analysis of sensory stimuli to form an appropriate response. Atypical sensory processing has been reported in approximately 90% of children with ASD [12]. Sensory processing abnormalities have been associated with disruptions in interpreting sensory inputs and deterioration in behavior patterns [13]. Restrictive and

selective eating attitudes can be observed in autistic children due to sensory sensitivities. Foods have many sensory properties; thus, food rejection may be more common in cases with sensory processing problems. According to the caregivers, autistic children reject certain foods due to their sensory characteristics, such as the food's consistency and texture, which may result in nutritional deficiencies or failure to thrive [14]. Considering the complex interaction of cognitive processes, sensory processing, and eating behavior is implicated to underly both other eating disorders and autism, as mentioned before, it would be appropriate to assume a similar association would exist for ARFID and autism however, although sensory processing is a defining feature for both, not all autistic individuals meet the criteria for ARFID, which could indicate a variance in autistic traits/symptoms and sensory profile compared to autism alone. As such, differences in these areas could also affect the quality of life of the individual.

This study aims to investigate the intricate relationship between autistic traits, sensory profiles and differences in eating attitudes, nutritional status, and quality of life in autistic children with ARFID. To that end, we had two hypotheses: (1) autistic children with ARFID, without ARFID and typically developing children have measurable differences in autistic traits, sensory processing, eating behaviors, anthropometric measurements, and quality of life (2) ARFID comorbidity in autism could be predicted in the clinical setting by one or more of the aforementioned variables. This study attempts to explore the relationship between eating behaviors, autism severity and autistic traits, sensory processing, and quality of life of autistic children with and without ARFID, and typically developing children aged 4–10 years.

Methods

Study Sample

Autistic children were recruited from an academic Child and Adolescent Psychiatry outpatient clinic. Thirty-seven children aged 4–10 years, diagnosed with ASD and comorbid ARFID comprised the ASD + ARFID group, and 37 children with ASD without ARFID, designated as the ASD-NoARFID group were included in the study regardless of gender. Age limits of 4 and 10 years were chosen to increase the chances of recruitment while minimizing the confounding effect of comorbidities associated with adolescence in autism. The typically developing children (TDC) with no history of developmental delays or psychiatric complaints were recruited through advertisements distributed to various parts of the university campus and were matched for age and gender. Verbal assent and written consent were sought from all participants and their parents. The present study was conducted per the ethical standards laid down in the 1964 Declaration of Helsinki and approved by the Ege University Clinical Research Ethical Committee (date:03.09.2020 no:20-9 T/58) ethics committee.

Participants were evaluated according to the DSM-5 criteria in two stages. The initial diagnostic assessment was performed by a child and adolescent psychiatry resident. The diagnoses were later confirmed by a senior child and adolescent psychiatrist with extensive experience in the field working with autistic individuals, with a non-structured clinical interview based on DSM-5 criteria. Currently, there are no Turkish versions of the Autism Diagnostic Interview-Revised (ADI-R) [15] or the Autism Diagnostic Observation Schedule (ADOS) [15] available. Consequently, the diagnosis of autism spectrum disorder relies

on clinical judgment, which is in line with the extants literature as the assessment conducted by skilled clinicians is regarded as the gold standard [16, 17]). Children with concomitant psychiatric disorders other than anxiety or other neurodevelopmental disorders, which includes mood and psychosis spectrum disorders according to DSM-5 or a history of neurological disorder or head trauma with prolonged loss of consciousness were excluded. The Childhood Autism Rating Scale was filled with information obtained from the parents concerning each item and direct observation of the children during the interview, and the children were subjected to an age-appropriate standardized test to assess their intelligence or development.

In the case of the comparison group, children aged 4–10 with no history of developmental delays, psychiatric complaints, or an existing psychiatric diagnosis were included in the study. A two-stage face-to-face interview was carried out as with the study group. The Childhood Autism Rating Scale was also completed for the participants in the comparison group during the interview, and the children were assessed clinically regarding their intelligence. Children who demonstrated an apparent delay in developmental milestones or had CARS scores above the designated cut-off of 29 or met the criteria for a psychiatric or neurodevelopmental disorder were excluded. Children without delays in development and psychiatric diagnoses were assigned to the TDC comparison group and included in the study.

Parents of the participants of each group were questioned regarding existing psychiatric disorders in themselves or their children during the interview. They were also asked to fill out the Child Eating Behavior Questionnaire (CEBQ), Social Responsiveness Scale (SRS), the Sensory Profile (SP), and the Pediatric Quality of Life Inventory (PedsQL) for their children.

Measures

Ankara Development Screening Inventory is designed as a culturally appropriate tool to evaluate the cognitive, motor, language, and social-emotional development of newborns, infants, and preschool children aged 0–6 years and older children lacking verbal capacity to complete other neurodevelopmental batteries. ADSI assesses normal development as well as identifies potential developmental challenges or delays. The information is provided by parents or caregivers, who actively observe and assess the child. The latest version of this tool includes 154 items and covers four domains: language and cognitive, fine motor, gross motor skills and social skills/self-care. A General Development Score is estimated as a sum of all domains [18]. ADSI was used to assess all autistic children younger than 6 years of age or children who were unable to complete WISC-R. The ADSI General Development scores in the present study are transformed into t-scores to facilitate comprehension and align it with the scoring used in WISC-R.

Child Eating Behavior Questionnaire (CEBQ): Developed by Wardle et al. CEBQ consists of 35 items filled out by the caregivers to assess the eating habits of children [19]. The items in the questionnaire were created with data obtained from previous literature on obesity and interviews with parents. In the Turkish validity and reliability study, CEBQ was shown to be a reliable psychometric tool in determining the eating behavior of Turkish children [20]. CEBQ is a valuable questionnaire for monitoring the eating behaviors of children, such as detecting aberrant eating habits, helping identify tendencies towards either obesity or weight loss, and to take the necessary precautions.

The Childhood Autism Rating Scale (CARS): CARS is a widely used scale to differentiate autism from other developmental disorders in light of information obtained from direct

observation of the children and information provided by the caregivers [21]. Scores above 30 support a diagnosis of autism, with higher scores indicating greater severity [22]. Turkish translation, reliability, and validity studies reported a Cronbach's alpha of .95 with high test–retest reliability ($r = .98$, $p < .01$) and inter-rater reliability ($r = .98$, $p < .01$) [23].

Social Responsiveness Scale (SRS): SRS has been shown to be a valid and reliable tool in detecting autistic traits, correlating significantly with autism symptoms [24]. The scale includes 65 items with a possible score between 0–195. Higher scores imply more significant social deficits and autistic traits. The Turkish version of SRS was found to be reliable according to a 6-month follow-up study [25].

Sensory Profile Caregiver Questionnaire (SP): Developed by Dunn in 1999 to assess sensory processing, this scale consists of 125 items rated by the caregiver of children aged 3–10 years. [26]. The sensory profile is used to evaluate sensory processing and its effects on functional performance in activities of daily living. Lower scores designate undesirable behavior and are indicative of higher sensory sensitivities. This study presents the quadrant scores and the sensory processing section of the sensory profile consisting of auditory, visual, vestibular, tactile, multi-sensory, and oral processing subcategories.

Dunn describes sensory processing in two dimensions: neurological threshold and self-regulation. A high neurological threshold indicates hyposensitivity; more sensory input is required to stimulate the individual. Thus, a low neurological threshold is associated with hypersensitive children easily overwhelmed by sensory stimuli. On the other hand, the self-regulation axis describes passive and active strategies to organize sensory information. Passive self-regulation is characterized by minimal behavioral intervention to control the flow of sensory information. In contrast, active self-regulation is characterized by utilizing behavioral strategies to increase or decrease sensory input. Behavioral and emotional qualities assessed by the SP are represented in four quadrants created by the intersections of these dimensions: low registration, sensation seeking, sensory sensitivity, and sensation avoiding.

Low registration is at the intersection of high neurological threshold and passive self-regulation. Children in this category seem less aware or lethargic, with limited interest in the world around them. Sensation-seeking children also have a high threshold; however, unlike low registration, they actively pursue sensory stimuli. The sensory sensitivity quadrant combines low neurological threshold and passive self-regulation. These children are easily overwhelmed by sensory stimuli, however, they seldom act to avoid situations with sensory overload. Instead, they may act out or appear uncomfortable and irritable in overstimulating environments. Sensation-avoiding children are similarly easily overwhelmed by sensory information as they also have a low neurological threshold. These children, however, employ tactics to decrease the flow of sensory input they receive from the environment. They may try to get away from loud environments or dampen noxious sensory stimuli (i.e., Wearing gloves or glasses to avoid certain tactile or visual stimuli). Turkish adaptation of the Sensory Profile Caregiver Questionnaire proved to be a valid and reliable tool for measuring sensory sensitivities in Turkish children [27].

Pediatric Quality of Life Inventory (PedsQL): PedsQL aims to measure the general quality of life in children and adolescents aged 2–18 and includes four different forms arranged according to the characteristics of the 2–4, 5–7, 8–12, and 13–18 age groups. This scale has a self-report and proxy form filled out by the caregiver [28]. PedsQL comprises four sections with physical, emotional, social, and school functioning scores. Emotional, social, and school functioning items are added to generate psychosocial functioning scores wh,ile all four scores are represented in a total score. Turkish validity and reliability studies were performed by Memik et al. and Üneri et al. for different age groups [29, 30].

Wechsler Intelligence Scale for Children-Revised (WISC-R) The WISC-R is a standardized intelligence test developed by Wechsler [31] for children aged 6–18, which consists of 12 subtests used to calculate verbal (VIQ) and performance IQ (PIQ) scores. Full Scale IQ (FSIQ) is calculated by summing VIQ and PIQ scores. The Turkish adaptation for WISC-R was found reliable, with Cronbach's alphas of 0.97 for VIQ, 0.93 for PIQ, and 0.97 for TIQ [32].

Statistical Analysis

Windows IBM SPSS v.25.0 was used for statistical analysis. Conformity of the data to normal distribution was evaluated with the Shapiro–Wilk test, histograms, and Skewness-Kurtosis coefficients. The mean and standard deviation values were used for normally distributed continuous data which was solely the BMI SDS variable in the present study, and the median and minimum–maximum values were used for data that violated normality assumptions. Kruskal–Wallis was used to evaluate differences in the SRS, CARS, SP, PedsQL, and CEBQ between the ASD + ARFID, ASD-NoARFID and TDC groups. Mann–Whitney U test was used for the assessment of FSIQ between ASD + ARFID and ASD-NoARFID groups. Post-hoc pairwise comparisons between the groups were also conducted with Mann–Whitney U or the student's t-test, and a Bonferroni correction was applied for multiple comparisons. Pearson chi-square was used to compare nominal data. Exploratory correlation analyses were conducted to identify differences in autistic traits, sensory processing, eating behaviors, anthropometric measurements, and quality of life in ASD + ARFID and ASD-NoARFID groups. Spearman's rho coefficients are given as the data was non-normally distributed with the exception of BMI SDS and SRS relationship as both were normally distributed, and as such the Pearson correlation coefficient is given. Potential predictors of ARFID in the presence of ASD were included in a multiple regression analysis to identify significant predictors for ARFID comorbidity in participants with ASD. Post-hoc receiver operator characteristic (ROC) curve analysis was used to designate potential cut-off points for significant continuous predictors of ARFID comorbidity in ASD. *p*-values less than .05 were considered statistically significant for all statistical analyses.

Results

The study sample consisted of 111 children aged 4–10, with 37 participants distributed equally into three groups. The first group consisted of autistic children with a concomitant ARFID diagnosis, the second group included autistic children, and the third group comprised typically developing age and gender-matched controls (TDC). The mean age of the participants was 6.40 ± 1.84, and 73.9% were male (n = 82). All participants were Turkish.

The exploration of the family characteristics of the participants revealed that the parents of the TDC had completed tertiary education significantly more than both other groups (*all* $p < .001$).

ASD + ARFIDD group had significantly lower height and weight SDS compared to both ASD-NoARFID and TDC groups ($p < .001$). Furthermore, the BMI SDS difference was significant between ASD + ARFID and ASD-NoARFID, with the latters' scores being higher ($p < .001$). FSIQ scores were also found to be higher in the ASD-NoARFID group compared to the ASD + ARFID group ($p = .010$). However, use of

any psychotropic medication was found to be similar in both ASD + ARFID and ASD-NoARFID groups (p > .05). The detailed socio-demographic characteristics of the participants with height, weight, BMI SDS, FSIQ and psychotropic medication use can be found in Table 1.

The eating behavior subscale scores between the groups were statistically significant for all categories except the desire to drink and emotional under-eating categories (all $p < .001$). Post-hoc pairwise analyses identified the scores for food responsiveness, enjoyment of food, and food fussiness scores were significantly lower (ASD + ARFID < ASD-NoARFID, ASD + ARFID < TDC; all $p < .001$), and satiety responsiveness and slowness in eating scores were significantly higher (ASD + ARFID > ASD-NoARFID, ASD + ARFID > TDC; all $p < .001$) for autistic children with ARFID compared to both the autistic and typically developing children. Additionally, the autistic children had higher emotional over-eating scores than autistic children with ARFID ($p < .001$).

The TDC had scored significantly higher in PedsQL physical, emotional, social, school functioning, psychosocial subdomains, and total scores compared to both ASD + ARFID and ASD-NoARFID groups (all $p < .001$). Regarding the PedsQL physical, emotional, school functioning, psychosocial subdomains, and total scores, no differences between ASD + ARFID and ASD-NoARFID groups were detected. However, ASD + ARFID group was found to have scored significantly lower than ASD-NoARFID in the social functioning subscale ($p = .001$). The Children's Eating Behavior Questionnaire and PedsQL subscale score comparisons between the groups are shown in Table 2 in detail.

The sensory processing scores (visual, auditory, vestibular, tactile, multi-sensory, and oral) and sensory profile quadrants scores (registration, seeking, sensitivity and avoidance) were found to be significantly different among the three groups (all $p < .001$). Post-hoc pairwise analyses were performed to identify which particular differences were significant. For the Auditory, Visual, Tactile, Multi-Sensory, and Oral categories, the TDC had higher scores than autistic children and autistic children with ARFID, respectively. (TDC > ASD-NoARFID > ASD + ARFID). In contrast, for the Vestibular category, TDC scored higher than both groups of autistic children (TDC > ASD + ARFID, TDC > ASD-NoARFID). Regarding the quadrant scores, seeking, sensitivity, and avoidance quadrant scores were highest for the TDC, followed by autistic children, with the autistic children with ARFID scoring the lowest (all $p < .001$; TDC > ASD-NoARFID > ASD + ARFID). For the registration quadrant, the TDC were found to have scored higher compared autistic children with and without ARFID (all $p < .001$; TDC > ASD + ARFID, TDC > ASD-NoARFID) with no difference between the two.

The Social Responsiveness Scale and Childhood Autism Rating Scale scores were both found to differ significantly among the groups. Post-hoc analyses revealed the SRS scores were highest in autistic children with ARFID, followed by autistic and typically developing children, respectively. (ASD + ARFID > ASD-NoARFID > TDC; $p < .001$). CARS scores were higher in autistic children with and without ARFID compared to TDC (ASD + ARFID > TDC; $p < .001$, ASD-NoARFID > TDC; $p < .001$). Further analyses were conducted for CARS Items 7 (Visual Response),8 (Listening Response) and 9 (Taste–Smell-Touch Response and Use). Item 7 and Item 8 scores were found to be higher in both autistic groups compared to typically developing children. (ASD + ARFID > TDC; $p < .001$, ASD-NoARFID > TDC; $p < .001$). For Item 9, autistic children with ARFID scored higher than autistic children, followed by typically developing children. (ASD + ARFID > TDC; $p < .001$, ASD-NoARFID > TDC; $p < .001$). The differences in sensory profile sensory processing and quadrant scores, SRS, CARS total and items 7,8,9 scores are summarized in Table 3.

Table 1 Socio-demographic data, height, weight, BMI standard deviation scores (SDS) of the participants

		ASD + ARFID		ASD-NoARFID		TDC						
		N *Med*	% *min–max*	*N* *Med*	% *min–max*	*N* *Med*	% *min–max*	*p*		p1	p2	p3
Gender	Female	9	31.0	10	34.5	10	34.5	.954		-	-	-
	Male	28	34.1	27	32.9	27	32.9					
Age		6.0	4.0–10.0	6.0	4.0–10.0	7.0	4.0–9.0	.803		-	-	-
FSIQ		80	30–121	100	60–36	-	-	.010*		-	-	-
Maternal Education	Secondary	25	39.7	30	47.6	8	12.7	<.001***	3 > 1, 3 > 2	.118	<.001***	<.001***
	Tertiary	12	25.5	6	12.8	29	61.7					
Paternal Education	Secondary	28	44.4	26	41.3	9	14.3	<.001***	3 > 1, 3 > 2	.465	<.001***	<.001***
	Tertiary	8	17.0	11	23.4	28	59.6					
Height		115	90–140	121	100–150	125	98–154	.001***	1 < 2, 1 < 3	.002**	.013*	1.000
Height SDS		-.67	-2.98–2.12	1.00	-2.66–2.98	.60	-1.85–2.98	<.001***	1 < 2, 1 < 3	<.001***	<.001***	.402
Weight		20	10–40	26	15–50	25	16–48	<.001***	1 < 2, 1 < 3	<.001***	<.008**	.756
Weight SDS		-.42	-2.23–1.74	1.32	-2.20–2.69	.44	-.55–2.75	<.001***	1 < 2, 1 < 3	<.001***	<.001***	.003**
BMI		16	8.26–31.40	17.78	11.81–37.19	16.21	13.61–22.49	.005**	1 < 2	.004**	.546	.167
BMI SDS *(mean, SD)*		-.26	1.30	.88	1.13	.21	.91	<.001***	1 < 2	<.001***	.068	.007**
Psychotropic Medication		11	29.7	5	13.5	-	-	.90		-	-	-
Antipsychotics		7	18.9	3	8.1	-	-					
Stimulants		3	8.1	2	5.7	-	-					
SSRIs		1	2.7	0	0	-	-					

Table 2 Child eating behavior questionnaire (CEBQ), and Pediatric Quality of Life Inventory (PedsQL) subscale scores of ASD + ARFID, ASD-NoARFID and TDC groups

	ASD + ARFID Mdn(min–max)	ASD-NoARFID Mdn(min–max)	TDC Mdn(min–max)	*p*		p1	p2	p3	Effect size (ε^2)
CEBQ									
Food Responsiveness	6 (5–14)	10 (5–25)	11 (5–23)	<.001***	2 > 1, 3 > 1	<.001***	<.001***	.948	0.55
Emotional Over-eating	4 (4–11)	6 (4–19)	6 (4–9)	.001**	2 > 1	<.001***	.004**	.293	0.36
Enjoyment of Food	11 (5–17)	16 (7–21)	15 (11–23)	<.001***	2 > 1, 3 > 1	<.001***	<.001***	.724	0.52
Desire to Drink	9 (3–15)	7 (3–15)	9 (3–15)	.986	-	-	-	-	0.02
Satiety Responsiveness	29 (16–35)	16 (7–29)	16 (7–27)	<.001***	1 > 2, 1 > 3	<.001***	<.001***	.441	0.73
Slowness in Eating	10 (4–20)	7 (4–17)	6 (4–18)	<.001***	1 > 2, 1 > 3	<.001***	<.001***	.943	0.42
Emotional Under-eating	8 (4–19)	10 (4–18)	10 (4–17)	.093	-	-	-	-	0.22
Food Fussiness	3 (3–5)	9 (13–15)	11 (4–15)	<.001***	2 > 1, 3 > 1	<.001***	<.001***	.006	0.77
PedsQL									
Physical	78.1 (0–100)	84.3 (50–100)	100 (75–100)	<.001***	3 > 1, 3 > 2	.335	<.001***	<.001***	0.60
Emotional	70 (0–100)	75 (15–100)	100 (70–100)	<.001***	3 > 1, 3 > 2	.142	<.001***	<.001***	0.69
Social	55 (0–95)	75 (25–100)	100 (95–100)	<.001***	3 > 2 > 1	.001**	<.001***	<.001***	0.82
School	80 (0–100)	90 (50–100)	100 (85–100)	<.001***	3 > 1, 3 > 2	.173	<.001***	<.001***	0.64
Psychosocial	73.3 (0–86.6)	83.3 (36.6–100)	100 (88.3–100)	<.001***	3 > 1, 3 > 2	.008**	<.001***	<.001***	0.81
Total	71.7 (0–91.3)	82.6 (46.7–100)	98.9 (86.9–100)	<.001***	3 > 1, 3 > 2	.021*	<.001***	<.001***	0.80

ASD + ARFID:Group 1, ASD-NoARFID: Group 2, TDC: Group 3, P1: Mann Whitney U between 1–2, P2: Mann Whitney U between 1–3, P3: Mann Whitney U between 2–3

*$p < .05$; **$p < .01$; ***$p < .001$

Table 3 Sensory Profile sensory processing scores and quadrant scores, Social Responsiveness Scale (SRS), Childhood Autism Rating Scale (CARS) total and items 7,8,9 scores of ASD + ARFID, ASD and TDC groups

	ASD + ARFID Median (min–max)	ASD-NoARFID Median (min–max)	TDC Median (min–max)	*p*		p1	p2	p3	Effect size (ε^2)
SRS	94 (41–157)	78 (38–120)	12 (3–39)	$<.001^{***}$	1 > 2 > 3	$.001^{***}$	$<.001^{***}$	$<.001^{***}$	0.85
CARS	36 (24–46)	32 (27–44)	15 (15–18)	$<.001^{***}$	1 > 3, 2 > 3	$.017^{*}$	$<.001^{***}$	$<.001^{***}$	0.81
CARS Item 7 (Visual)	2 (1–3)	2 (1–3)	1 (1–2)	$<.001^{***}$	1 > 3, 2 > 3	.429	$<.001^{***}$	$.001^{***}$	0.50
CARS Item 8 (Listening)	3 (1–4)	2 (1–4)	1 (1–2)	$<.001^{***}$	1 > 3, 2 > 3	.759	$<.001^{***}$	$<.001^{***}$	0.66
CARS Item 9 (Taste–Smell-Touch)	4 (1–4)	2 (1–4)	1 (1–1)	$<.001^{***}$	1 > 2 > 3	$.001^{***}$	$<.001^{***}$	$<.001^{***}$	0.76
Sensory Processing									
Auditory	21 (9–38)	30 (8–40)	40 (33–40)	$<.001^{***}$	3 > 2 > 1	$.013^{*}$	$<.001^{***}$	$<.001^{***}$	0.75
Visual	36 (13–45)	45 (20–45)	45 (39–45)	$<.001^{***}$	3 > 2 > 1	$.008^{**}$	$<.001^{***}$	$.001^{**}$	0.59
Vestibular	45 (23–55)	48 (24–55)	55 (51–55)	$<.001^{***}$	3 > 1, 3 > 2	.215	$<.001^{***}$	$<.001^{***}$	0.70
Tactile	68 (36–90)	81 (45–90)	89 (85–90)	$<.001^{***}$	3 > 2 > 1	$.001^{**}$	$<.001^{***}$	$<.001^{***}$	0.74
Multi-sensory	23 (11–33)	29 (12–35)	35 (30–35)	$<.001^{***}$	3 > 2 > 1	$<.001^{***}$	$<.001^{***}$	$<.001^{***}$	0.78
Oral	23 (12–40)	55 (15–60)	59 (54–60)	$<.001^{***}$	3 > 2 > 1	$<.001^{***}$	$<.001^{***}$	$<.001^{***}$	0.80
Quadrants									
Registration	59 (29–75)	65 (19–75)	75 (69–75)	$<.001^{***}$	3 > 1, 3 > 2	.051	$<.001^{***}$	$<.001^{***}$	0.73
Seeking	84 (52–115)	107 (60–130)	128 (116–130)	$<.001^{***}$	3 > 2 > 1	$<.001^{***}$	$<.001^{***}$	$<.001^{***}$	0.82
Sensitivity	66 (33–80)	85 (57–97)	97 (86–100)	$<.001^{***}$	3 > 2 > 1	$<.001^{***}$	$<.001^{***}$	$<.001^{***}$	0.85
Avoidance	108 (62–134)	122 (81–141)	148 (130–150)	$<.001^{***}$	3 > 2 > 1	$<.001^{***}$	$<.001^{***}$	$<.001^{***}$	0.82

Autism + ARFID:Group 1, Autism: Group 2, TDC: Group 3, P1: Mann Whitney U between 1–2, P2: Mann Whitney U between 1–3, P3: Mann Whitney U between 2–3

$^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$

Exploratory correlation analyses were conducted to identify any significant associations between the predictor variables and ARFID, which would then be further investigated using multiple regression analysis. The variables of interest were identified as FSIQ, BMI SDS, SRS, CARS, CEBQ subscales, and SP Sensory Modalities. We incorporated sensory modalities rather than quadrants in the analysis, as they provided a better framework for investigating the hypothesis behind Avoidant/Restrictive Food Intake Disorder (ARFID), which involves sensory aversion to food. The PedsQL scale was not included in the analysis as the quality of life was more attributable to the concurrent presence of autism and ARFID rather than being predictive of ARFID. FSIQ was inversely correlated with both measures of autistic symptomatology of SRS ($r = -.36$, $p = .002$) and CARS ($r = -.32$, $p = .001$). BMI SDS was also extensively correlated with CEBQ subscales except desire to drink and emotional undereating; as well as oral processing scores ($r = .44$, $p < .001$). Oral processing scores were extensively correlated with all subscales of CEBQ except desire to drink and emotional undereating domains, with satiety responsiveness ($r = -.72$, $p < .001$) and food fussiness ($r = .72$, $p < .001$) exhibiting strong correlations, respectively. Both SRS and CARS showed positive moderate levels of correlation with all sensory processing modalities (*all* $p < .001$) and were also correlated with one another ($r = .54$, $p < .001$). There was also a moderate correlation among all sensory modalities (*all* $p < .001$). A summary of the detailed results from the exploratory correlation analyses can be found in Table 4.

Multiple logistic regression analysis was conducted to determine the predictors of ARFID in autistic children (n = 74). Variables that represented IQ, nutritional status, autistic traits and sensory processing with statistically significant differences between ASD + ARFID and ASD-NoARFID were included in the analysis. Nutritional status was represented with anthropometric measurements, which included height, weight, and BMI SDS. BMI SDS was selected to be included in the regression analysis as all three metrics were significant between the two groups, and BMI SDS represented both weight and height SDS. Although FSIQ and measures of autistic symptomatology were correlated, the relationship between them was weak, as evidenced by the correlation coefficients, and were deemed non-multicollinear. However, SRS instead of CARS was included as a measure for autistic symptomatology as total scores differed significantly between ASD + ARFID and ASD-NoARFID groups. CEBQ subscales were omitted in favor of oral processing as the relationship between oral processing and several subsclaes of the CEBQ were multicollinear. Finally, FSIQ, social responsiveness scale scores and auditory, visual, tactile, and oral sensory processing scores were included in the regression to account for autistic traits and sensory processing differences. Multiple logistic regression analysis revealed that oral processing scores significantly predicted ARFID comorbidity in autism, with the odds of a comorbid ARFID diagnosis decreasing by 19.2% with each point increase in the oral sensitivity section of the Sensory Profile, in which higher scores correspond to a decrease in sensitivity and lower scores indicate increased sensitivity in the measured sensory modality. The results of the multiple regression analysis are summarized in Table 5.

A possible cut-off value to identify autistic children with ARFID via Sensory profile oral processing scores was investigated with the ROC curve. The area under the curve was found to be 0.919, with a 95% confidence interval of 846-.991 (Fig. 1). The potential cut-off scores with their respective sensitivity, specificity and positive likelihood ratios (LR+) are presented in Table 6.

Table 4 Exploratory correlation analysis for Child eating behavior questionnaire (CEBQ), Social Responsiveness Scale (SRS), Childhood Autism Rating Scale (CARS) and Pediatric Quality of Life Inventory (PedsQL) and Sensory Profile in ASD + ARFID and ASD-NoARFID groups

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. FSIQ	-																
2. BMI	.21	-															
3. Food Responsiveness	.14	.47***	-														
4. Emotional Over-eating	.16	.41***	.64***	-													
5. Enjoyment of Food	.07	.42***	.69***	.42***	-												
6. Desire to Drink	.14	.23	.11	.05	.06	-											
7. Satiety Responsiveness	-.20	-.57***	-.69***	-.51***	-.54***	.09	-										
8. Slowness in Eating	-.15	-.45***	-.57***	-.28*	-.59***	-.14	-.61***	-									
9. Emotional Undereating	-.04	.11	.25*	.31**	.11	.02	-.15	.20	-								
10. Food Fussiness	.07	.43***	.64***	.51***	.62***	-.08	-.74***	-.44***	.29*	-							
11. SRS	-.36**	-.21[a]	-.12	-.11	-.26*	.03	.25*	.21	.08	-.18	-						
12. CARS	-.32**	-.18	-.15	-.09	-.38**	.21	.23*	.31**	-.01	-.18	.54***	-					
13. Auditory	.20	.21	.16	-.03	.26*	-.15	-.28*	-.29*	-.11	.25*	-.45***	-.52***	-				
14. Visual	.22	.24*	.13	.11	.14	.04	-.30**	-.17	.09	.12	-.43***	-.40***	-.38***	-			
15. Vestibular	.33**	.01	.03	-.05	.09	-.18	-.19	-.16	-.16	.09	-.41***	-.46***	-.54***	-.33***	-		
16. Tactile	.16	.22	.22	.08	.29*	-.20	-.46***	-.30*	-.01	.37**	-.42***	-.42***	-.42***	-.47***	-.55***	-	
17. Multi-sensory	.24*	.24*	.19	.19	.31**	-.09	-.34**	-.20	-.03	.30*	-.41***	-.55***	-.54***	-.43***	-.44***	-.48***	-
18. Oral	.27*	.44***	.51***	.32**	.59***	-.12	-.72***	-.51***	.10	.72***	-.44***	-.43***	-.49***	-.45***	-.42***	-.64***	-.49***

*$p < .05$; **$p < .01$; ***$p < .001$

Table 5 Multiple logistic regression analysis for prediction of ARFID in autistic children (n = 74)

	B	Std. Error	Wald	df	*p*	OR	95% CI	
							LL	*UL*
Full Scale IQ	.052	.033	2.426	1	.119	1.053	.987	1.123
Social Responsiveness Scale	.249	.341	.533	1	.465	1.283	.657	2.504
Body Mass Index SDS	-.021	.026	.664	1	.415	.979	.932	1.03
Auditory sensory processing	-.089	.092	.932	1	.334	.915	.763	1.096
Visual sensory processing	-.017	.068	.065	1	.798	.983	.861	1.122
Tactile sensory processing	-.026	.043	.361	1	.548	.974	.895	1.061
Multi-sensory processing	.092	.092	.998	1	.318	1.097	.915	1.314
Oral sensory processing	.192	.052	13.665	1	< .001	1.212	1.095	1.342

Discussion

Sociodemographic Differences

To our knowledge, this is the first study to investigate the eating behaviors, sensory profiles, and quality of life in autistic children with ARFID as well as potential predictors of ARFID comorbidity in autistic children.

The participants across all groups had similar demographic characteristics in terms of age and gender. However, the groups had various socio-demographic differences. For instance, the parents' education level of the typically developing children in the comparison group was higher than that of both the autistic children with and without comorbid ARFID. The effects of socioeconomic and education levels of the parents on autism diagnosis are inconsistent with an increased risk of ASD diagnoses reported with both high [33, 34] and low socio-economic status of the parents' [35, 36] and some studies reporting no association at all [37]. Although TDC had higher parental education levels, no significant difference was found among autistic children with and without ARFID. Furthermore, in our sample ASD + ARFID and ASD-NoARFID groups were found to be similar in terms of medication use. This finding likely stems from characteristics within our sample rather than signifying any compelling implications. It is noteworthy that the initiation of pharmacotherapy in autism spectrum disorders is often linked to behavioral symptoms rather than sensory disturbances [38], which could explain the absence of observed differences between the groups.

Anthropometric and IQ Differences

In our study, the BMI, height, and weight standard deviation scores (SDS) were the lowest in autistic children with ARFID. Substantial weight loss or lack of weight gain is listed among the diagnostic criteria of ARFID [1]. As such, it is emphasized that since most children diagnosed with ARFID are chronically underweight, treatment plans should be made accordingly [39]. Autistic children more often have eating problems than children with typical development [40, 41]; however, undereating is only one end of the spectrum for disordered feeding. The prevalence of obesity is reported to be higher in autistic individuals

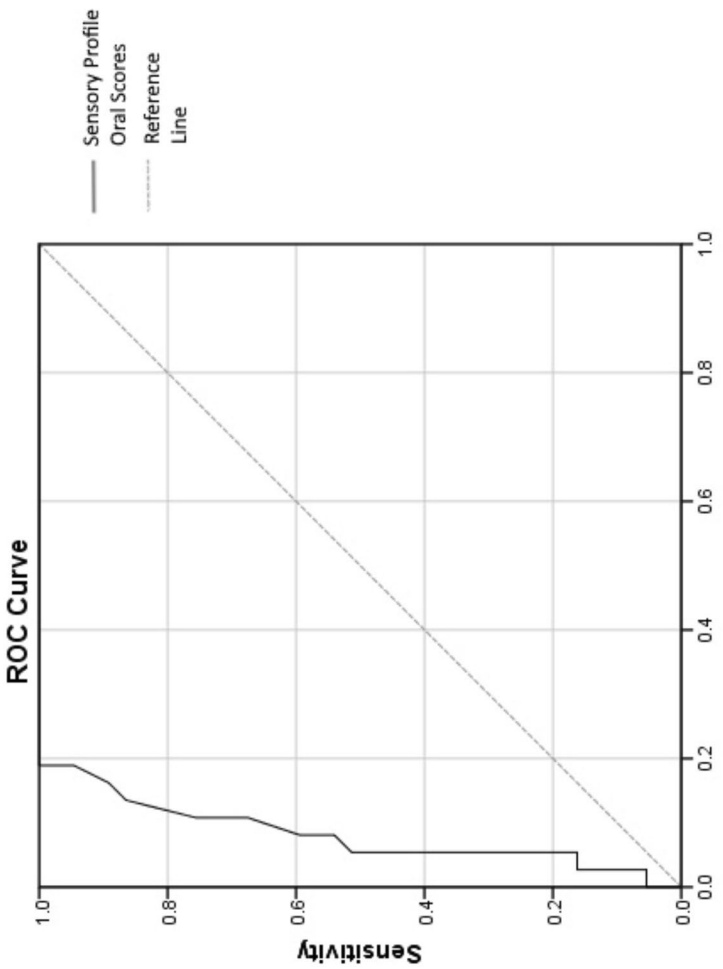

Fig. 1 ROC curve for Sensory Profile Oral Sensory Processing scores (AUC = .919, CI95% = .846–.991)

Table 6 ROC curve sensitivity, specificity, PPV, NPV and LR for Sensory Profile Oral Processing scores (AUC = .919, CI95% = .846-.991)

Cut-off	Sensitivity	Specificity	PPV	NPV	LR (+)
28.5	86.5	86.5	86.5	86.5	6.4
30.5	89.2	83.8	84.6	88.6	5.5
34.5	94.6	81.1	83.3	93.8	5.0
38.5	97.3	81.1	83.7	96.8	5.1

than in the general population [42]. Although it was not statistically significant, the weight SDS of autistic children without ARFID was found to be higher than the control group in our study. This finding highlights the importance of close monitoring of weight and development in autistic children, even in the absence of an eating disorder, which is in line with the existing literature as regular monitoring of the BMI of children by their caregivers is recommended [43].

Regarding IQ, ARFID + ASD group scored lower on the Full Scale IQ (FSIQ) compared to the ASD-NoARFID group. We found that sensory processing differences were more pronounced as a significant yet modest correlation between vestibular, multisensory, and oral sensory sensitivity scores and IQ was found. While a consensus has not been reached regarding the co-occurrence of ASD and intellectual disability in relation to sensory processing [44], there have been reports suggesting heightened sensory atypicalities in children with intellectual disability and impaired adaptive behavior [45, 46]. In addition, FSIQ was inversely correlated with autistic traits and symptomatology, although the correlation coefficient was low in the present study. IQ is reported to influence the presentation of autistic symptomatology [47] and also has an impact on adaptive behaviors, which may also moderate the observation of autistic traits [48]. The interplay between IQ and sensory processing is a complex topic, especially in the context of autism and ARFID. While there is a growing body of research on both autism and ARFID, the specific connection between IQ and sensory processing and how they impact eating behavior in autism remains understudied. In our study, FSIQ was not found to be a predictor of ARFID in autistic children.

Eating Habits

The CEBQ takes into account both the children's attitude toward eating and the quality of the feeding [49]. Of the CEBQ subcategories, slowness in eating and satiety responsiveness scores were found to be significantly higher, and food fussiness, enjoyment of food, and food responsiveness scores were lower in ASD + ARFID group compared to both ASD-NoARFID and TDC groups. In addition, ASD-NoARFID group had higher emotional over-eating scores than the ASD + ARFID, supporting our hypothesis that autistic children with ARFID have different eating habits compared to both autistic children without ARFID and typically developing children. Similar to our study, the CEBQ subscales of satiety responsiveness and slowness in eating were found to be higher, and food responsiveness and enjoyment of food were also found to be lower in a group of children with ARFID, although they did not have comorbid autism [50]. Considering the ASD group scored higher in emotional over-eating compared to the ASD + ARFID group but not the TDC group and also had the highest weight and BMI SDS scores in our sample, over-eating and obesity should be investigated in autistic children. Since ASD could also be associated with fussy or picky eating habits, and overall eating problems [51], screening is

recommended in children with atypical eating patterns due to the significantly higher prevalence of ARFID and other eating disorders, as well as obesity, in autistic children [14, 52].

Quality of Life and Autistic Symptoms

The quality of life of autistic individuals with ARFID as well as autistic symptomatology both in the form of core symptoms measured by CARS and autistic traits and social reciprocity by SRS were investigated in our study. While both groups of autistic children scored significantly lower than the TDC in all domains of quality of life in the present study, which is in line with the existing literature [53, 54]; autistic children with ARFID scored demonstrably lower than autistic children without ARFID on the social functioning subscale of the PedsQL. This is further supported by several reports of ARFID causing individuals to isolate themselves in mealtimes, which are particularly important to autistic children as they may already have difficulties in social integration and participation [55]. However, it is worth noting that IQ plays a significant role as a predictor of quality of life, social skills, and autistic symptoms in children with autism, which could potentially account for the variations observed in our study sample. This could also explain the difference in SRS scores, as they were found to be the highest in the ASD + ARFID group, followed by the ASD-NoARFID and TDC, respectively, pointing to a difference in autistic traits as measured by impairment in social reciprocity. An effective tool in diagnosing autism and designating the severity of its symptoms, [56] CARS scores in our study were found to be higher for autistic children with and without ARFID compared to typically developing children as was anticipated. However, no statistical difference was found between ASD + ARFID and ASD-NoARFID groups. This also held true regarding the visual and listening response items of CARS, however, ASD + ARFID group scored higher on taste–smell-touch response and use compared to ASD-NoARFID group, probably due to gustatory sensory differences which resluts in selective preferences regarding food [57]. This item provides less information on sensory modulation as it does not make a distinction betwen different modalities of sensory processing, which will be elaborated further upon in the Sensory Processing section.

Sensory Processing

In the present study, the sensory profile scores (auditory, vision, tactile, multi-sensory, oral sensory processing as well as seeking, sensitivity, and avoidance quadrant scores) were highest in the TDC followed by, ASD-NoARFID and ASD + ARFID groups, respectively, while registration quadrant and vestibular sensory processing scores were higher in the TDC than in both ASD + ARFID and ASD-NoARFID groups. These findings highlight that autistic children with ARFID have significant impairments in sensory processing, which may have contributed to their restricted eating. This is consistent with the results of previous studies. Autistic children are known to score differently than their typically developing peers on as much as 85% of the sensory profile items, and nearly 90% are reported to have atypical sensory processing [58, 59]. Also, autistic children have been found to have explicit differences in processing specific sensory modalities as they scored differently in auditory, visual, tactile, and oral sensory processing sensory profiles compared to the controls [60]. Especially, children with oral sensory sensitivity are more likely to be picky eaters [58], and disruptions in sensory processing correlate with eating problems [13, 61]. Although not assessed by the sensory profile, the co-occurrence of olfactory sensitivities

and eating problems also suggests that sensory processing plays an important role in eating behavior [13, 62]. The relationship between autistic traits and the sensory profile is reported in the literature as well. Hilton et al. reported a negative correlation between all quadrant scores of the sensory profile and social responsiveness scale scores in children with high-functioning ASD [63]. Low registration and sensory sensitivity scores were reported to be more closely associated with autism symptomatology and autistic traits [64]. In addition, the relationship between autistic traits and picky eating habits are also firmly established. However, no studies were found that account for the interplay of autistic traits and sensory processing in ARFID comorbid autistic children.

In our study, multiple logistic regression with BMI SDS, SRS and auditory, visual, tactile, multi-sensory and oral sensory processing scores as predictors and controlling for FSIQ revealed that only oral sensory processing scores of the Sensory profile were significant in the prediction of ARFID in autistic children. The Sensory Profile oral processing scores were also found to have the potential to detect ARFID comorbidity in autistic children. Although scores lesser than 38.5 identified children with ARFID in the sample of autistic children of our study with 97.3% sensitivity and 81.1% specificity; 28.5 offers better specificity (86.5%) with a slight decrease in sensitivity (86.5%); which indicates that Sensory profile oral scores were effective in screening for ARFID in our outpatient sample of autistic children. The fact that autistic children with ARFID differ from their peers with autism and typical development, especially in oral sensory processing, may prove useful in detecting ARFID, as ARFID comorbidity in autistic children had scored significantly lower quality of life than their typically developing peers and also substantially lower in social quality of life than their autistic peers. Indeed, social responses and feeding behaviors are not entirely unrelated. Gustatory and olfactory centers in the brain are known to be important centers in regulating emotional and social responses [65]. One such study comparing sensory processing differences between autistic children and their typically developing peers employed functional magnetic resonance imaging (fMRI) after the participants completed the Sensory Profile. It was found that the children with oral sensory sensitivity had aberrant connection patterns between the primary taste center and social regions of the brain [66], providing further support to the hypothesis that altered oral sensitivity is connected to both abnormal eating habits and difficulties in social interaction in a subgroup of children. As such, identifying the ARFID comorbidity in autistic children is important both in terms of screening for differences in their nutritional status and social quality of life.

Strengths and Limitations

This study contributes to the extant literature on the comorbidity of autism with eating disorders. Considering the limited number of studies on ARFID and ARFID comorbidity on autism, the present study both supports and adds to the current literature on a relatively little-studied subject while also providing insight into the sensory profile, eating habits, and quality of life of autistic children with ARFID. The fact that most of the studies on this topic have been carried out in Western populations is also among this study's strengths, as our findings are derived from a non-Western sample.

The relatively small sample size is a significant limitation of the present study. Our sample size may be insufficient to discern specific differences between groups, since the power analysis was initially based on the assumption of using ANOVA. However, since our data exhibited non-normal distribution across all variables of interest Kruskal–Wallis was used

instead. Comparable numbers of participants in the study and control groups matched for age and gender is an important strength.

However, the study groups were recruited from a tertiary referral hospital, Child and Adolescent Psychiatry Outpatient Clinic, and the comparison group came via adverts on put on the university campus, which may have resulted in fairly homogeneous groups. The inclusion of standardized and culturally appropriate developmental tools to control for IQ in the ASD groups considerably adds to the study. However, the same standardized tests could not be applied to the TDC, which is an important limitation. Our study also included children aged 4–10 to reduce the confounding effect of comorbidities associated with adolescence. However, a caveat of the inclusion of young children is that caregiver reports in the form of questionnaires constitute the primary basis of data collection in the present study, which may lead to a proxy response bias. Another similar limitation is the reliance on parent reports' in familial psychiatric history, as no formal psychiatric assessments were carried out with the parents. The cross-sectional nature of this study, while providing an accurate snapshot, also impedes its generalizability across other age groups. Thus, more studies with greater sample sizes and prospective designs are needed to effectively investigate the sensory profiles, eating habits, and quality of life of autistic children with ARFID.

Conclusions

This study highlights a clear difference in eating habits, autistic traits and social quality of life for autistic children with comorbid ARFID compared to both autistic and typically developing children, although this could be moderated by IQ. In addition, having a diagnosis of ARFID is also associated with a different sensory profile compared to both autistic and typically developing children. The difference in this sensory profile seems to be driven by oral sensory processing independent of both autistic traits, BMI and IQ. Also, oral sensory processing scores measured by the sensory profile could also serve as a screening tool for identifying ARFID comorbidity in autistic children. It would seem a combination of sensory deficits and autistic traits, negatively impacts the quality of life of autistic children with ARFID, underscoring the importance of screening for this eating disorder as both anthropometric growth measurements indicating nutritional status, and social quality of life seem to be affected in this group. Thus, detecting ARFID in autistic children is important as both the nutritional and social demands of this subgroup seem to be different from their peers, which could affect clinical and treatment approaches.

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Data Availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethics Statement The presented study was conducted per the ethical standards laid down in the 1964 Declaration of Helsinki and approved by the Ege University Faculty of Medicine Ethics Committee of Clinical Research (No:20-9 T/58).

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Conflicts of Interest The authors declare no conflicts of interest.

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Reyhan Calisan-Kinter, M.D. graduated from Dokuz Eylul University Faculty of Medicine and successfully completed her child and adolescent psychiatry residency training in Ege University Faculty of Medicine. Her interests include neurodevelopmental disorders including autism spectrum disorders with a special interest in eating disorders, among them anorexia nervosa, bulimia nervosa, binge eating disorder and avoidant restrictive food intake disorders.

Burcu Ozbaran, M.D. received her degree in Ege University Faculty of Medicine and started the Child and Adolescent Psychiatry Residency Program following her graduation. She has completed the analytic psychotherapy training in Izmir Odag Psychoanalysis and Psychotherapy Association including individual and group psychotherapy training and supervisions. She is also a certified play therapist and has a background in family therapy. Her interests include social cognition and emotion regulation, theory of mind and working memory, anorexia and bulimia nervosa, attention deficit hyperactivity disorder, autism spectrum disorders, neurodevelopmental psychology and psychopathology and child and adolescent trauma and abuse. She has also authored several books on child-rearing, care and parental guidance. She is also proficient in English and German.

Ipek Inal Kaleli, M.D. graduated from Acibadem School of Medicine and completed the Chemical Dependence Rehabilitation Clinical Elective Program at Cleveland Clinic Lerner College of Medicine and Psychiatry Acute Care Subinternship Program at Mayo Clinic College of Medicine and Science. She is currently pursuing an ECFMG certification, having satisfied the medical examination requirements and is presently a child and adolescent psychiatry resident at Ege University Faculty of Medicine. Her interests include neurodevelopmental disorders, neuropsychiatry, emergency psychiatry and addiction psychiatry.

Sezen Kose, M.D. graduated from and completed the child and adolescent residency program at Ege University Faculty of Medicine. She is presently a practising child and adolescent psychiatrist and Associate Professor in Child and Adolescent Psychiatry at Ege University Faculty of Medicine., Her interests include social cognition and emotion regulation, anorexia and bulimia nervosa, attention deficit hyperactivity disorder, autism spectrum disorders, neurodevelopmental psychology and psychopathology and child and adolescent trauma and abuse. She has received various awards including first place in several refereed congress and proceedings. She has numerous published manuscripts in revered international journals; including reviews and meta-analyses and has received national grants in her leading research on autism spectrum disorders.

Tezan Bildik, M.D. is a Professor of Child and Adolescent Psychiatry at Ege University Faculty of Medicine. She completed her medical training and residency in child and adolescent psychiatry in Ege University Faculty of Medicine. She currently holds the Head of the Child and Adolescent Psychiatry title in her alma mater. She is currently a member of Cognitive and Behavioral Therapy Association, a national organization recognized by International Association for Cognitive Psychotherapy (IACP). She has several published articles both in esteemed national and international journals. She has supervised multiple dissertations in child and adolescent mental health. Her interests include bipolar and psychotic disorders in adolescents, mood disorders, sexual and psychical abuse in youth, psychodynamic child and adolescent psychotherapy, identity development and separation-individuation in adolescence.

Mohammad Ghaziuddin, M.D. is a child & adolescent psychiatry specialist in Ann Arbor, MI and has over 20 years of experience in the medical field. He graduated from the University of Health Sciences / Osmania Medical College in 2005 and completed his specialist training in Farnborough/Kings College Hospital in England. He served as a fellow in mental retardation psychiatry in the University of Nottingham in the UK and child and adolescent psychiatry at University of Michigan in Ann Arbor, USA. He is currently affiliated with the University of Michigan. Dr. Ghaziuddin has extensive experience in General Mental Health Disorders & Therapy and Neurodevelopmental Disorders. His current areas of interest include Developmental disorder, Autism/Pervasive Developmental Disorders, Asperger syndrome: Nosology, Phenomenology, Comorbidity, Family Studies and Mental Retardation: Psychopathology, Behavioral Phenotypes.